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To establish the needed science and technology [redacted] future Army battle-space capabilities, innovative research is sought in the general areas of THz frequency se[redacted]ence and advanced device concepts that facilitate robust functionality at frequencies within the submillin[redacted]ve or THz frequency regimes (i.e., the part of the electromagnetic spectrum between approximate[redacted] (300 GHz) and 100 µm (3 THz). To improve device performance, the Army is interested in new devi[redacted]ircuit concepts, including quantum transport devices such as resonant tunneling structures, and quantum-tran[redacted]vices in which photon emission can occur through intersubband transitions between quasi-bound st[redacted]also includes traditional devices with revolutionary circuit and packaging techniques to improve performar[redacted] components of particular interest are electrically-driven room-temperature sources, cw or pulsed, operat[redacted]een ~ 0.3 and 3 THz. Innovative and novel methodologies should be explored until an effective approach i[redacted]red or developed. Here, the development of efficient sources and integrated semiconductor-based co[redacted] and systems is a priority.
In addition, a key application of interest for tera[redacted] ultrafast electronics is battlefield remote sensing of biological agents. Another second class of appl[redacted] point detection of biological/chemical agents and explosives, such as RDX and TNT that also inte[redacted] THz radiation via low-frequency vibrations and rotational modes. Rapid, unambiguous identification of ch[redacted]gents, precursors, and degradation products is required in many areas of the DoD including treaty verifica[redacted]counter-terrorism. The ultra-high resolution offered by THz spectroscopy may provide this rapid identificati[redacted]when the substance is in a complex mixture. A final, and possibly even more far-reaching application of [redacted]tronics, is in the development of concepts for extending ultra-wideband sensing and communications. I[redacted]e fusion of an advanced THz-frequency sensing capability with conventional sensor-network communicati[redacted]igh-speed data processing has the potential for significantly enhancing the network-centric capability of the [redacted]Future Combat System of Systems (FCSS) concept. Here, THz electronics will collectively impact spectro[redacted]nsing, radiometric imaging and data transmission/ processing. Furthermore, commercial local-are[redacted]s networks can already be envisioned at frequencies as high as 400 GHz, therefore, THz electronics has a str[redacted] use potential and the potential for significantly impacting the high-frequency electronics of the future.

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RESEARCH AREA 5
COMPUTING AND INFORMATION SCIENCE

5.0. The Army has determined from its experience in Gulf Wars that it needs a force that can be deployed rapidly to any conflict area in the world. The delay incurred in deploying a heavy force with 70 ton tanks is no longer acceptable nor is the logistics tail needed to support them. The Army has embarked on a transformation to a lighter more rapidly deployable and supportable force. This, according to The Army Vision, will be a strategically responsive force that can deploy combat-capable forces anywhere in the world.

The operational concept of the Objective Force includes smaller units with higher mobility and weapons of greater precision and lethality. Since forces will not be highly massed and vehicles will have less physical protection, the key to providing survivability of this force is real-time information on the friendly and enemy situations available continuously so that decisions can be made and actions taken within the decision cycle of the enemy.

Information processing on the move is critical to the success of operations of the Objective Force which will be almost constantly moving. Information must be communicated; and, since the force is mobile, the communications required is unique mobile wireless communications networks that are adaptive and operate without any geographically fixed infrastructure. There will be numerous unmanned robotic and tele-operated aerial and ground vehicles serving as sensor, communications relay, and weapons systems platforms. Information sources on the battlefield will grow rapidly. Computing and information processing research will have to provide the technology to process this information in real-time and to insure that soldiers and commanders are not overburdened with data, rather than succinct information, to a degree that adversely affects their performance and victory in battles.

The transformation of the Army to the Objective Force will require investment in science and technology, especially computing and information science (CIS). The research topics described in this section of the BAA are those needed to provide the Objective Force with the information processing and communications needed to achieve the vision of future Army operations.

The CIS research at the Army Research Office required to support the characteristics of the Objective Force and the Future Combat System (FCS) center around techniques to gather, disseminate, and act upon information about the enemy's location, movement, and intention. Information from many different information sources will have to be fused to produce an incisive total picture of the battlefield. This composite of information must then be communicated quickly to both men and machines. Methods to aid the commander in using this information effectively must be developed. Decisions generated by the commander must result in unified action plans communicated quickly by electronic systems. CIS also will play a key role in providing an increased efficacy in both range and kill probability of weapon systems while effectively protecting our own forces. For this reason, CIS is a key technology, underpinning the FCS and the Objective Force. While advances in electronic technology have played decisive roles in recent successful military engagements, such as Desert Storm; the ambitious goals of these new warfighting concepts require major additional progress in the computing and information science discipline.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a preproposal or white paper.

5.1. Mobile, Wireless Communications and Networks. The mobile, wireless communications and networks research program is concerned primarily with establishing the fundamental understanding necessary to support the Army's future mobile, wireless tactical battlefield communications needs. The research in this program primarily targets the tactical battlefield at brigade and below. The Army is interested in communication systems operating in frequency bands traditionally occupied by narrowband radios high frequency (HF), very high frequency (VHF), and ultrahigh frequency (UHF) as well as systems operating in frequencies extending into the millimeter wave region. These systems must support broad-based and highly mobile communications and must perform in environments of impressive diversity, from dense foliage to dense urban obstructions, and unintentional and intentional jamming. Future Army tactical communication systems for the digital battlefield will consist of many different types of networks and must be capable of communicating on the move. These systems will be highly mobile creating highly dynamic network topologies (mobile ad-hoc networks) and routing multimedia (voice, data and video) data. Unlike commercial systems, the communications infrastructure must be mobile. In addition to the highly mobile communications, there is interest in algorithms for small, very energy-limited, stationary, unattended ground sensors.

5.1.1. Research is required in broad thrust areas including end-to-end admission, flow and congestion control; adaptive routing protocols; channel access protocols; adaptive transmission techniques for power and spectral efficiency; and signal processing for robust communications. Adaptability at all levels and cross layer design should be considered to meet quality of service (QoS) requirements where possible and optimize performance. Cross layer design may be the key to meeting the various QoS requirements and priorities of the network.

5.1.2. Research in multimode transport layer to be able to adapt to different networking environments. Unlike traditional TCP, the transport layer must be robust to packet errors as well as congestion. Admission, flow, and congestion control must be performed in the context of different QoS requirements and priorities. Network control must be distributed to avoid single points of failure and the system should be self-organizing with peer-to-peer capability.

5.1.3. Routing protocols must be able to adapt to the constantly changing environment caused by mobility, propagation conditions, interference environment, and traffic load changes. In contrast to classical routing, that sends all traffic over the "best" path, adaptive tactical routing protocols should utilize all network resources, optimizing the route for the QoS of the particular packet. Routing protocols must be designed to handle point-point, multicast, broadcast, and possibly anycast multimedia traffic. Mathematical and simulation models are desired to evaluate routing protocols for use in tactical military communications.

5.1.4. Channel access is expected to play a central role in providing efficient QoS. Of particular interest are channel access protocols that are distributed, scalable, adaptive, survivable, secure, and energy efficient. Novel protocols are needed for link scheduling to support directional antennas, steerable arrays, and space time coding; protocols permitting low-latency access for a mixture of multi-media traffic types; protocols incorporating adaptive power control techniques for purposes of energy efficiency and to reduce interference; and methods providing diverse QoS guarantees.

5.1.5. The physical layer will utilize some form of spread spectrum packet radio. Research is sought which supports spread spectrum, multiple access, anti-jam and covert (low probability of detection/interception) capabilities, and adaptive antenna array processing. Research in adaptive data compression and adaptive error control coding is also relevant.

5.1.6. Research in smart antenna techniques for communications is of interest. This includes array processing for null and beam steering adaptive antennas, direction of arrival estimation, diversity combining techniques, as well as multiple-input multiple output (MIMO) techniques.

5.1.7. There is an interest in basic research to develop theory to support the design of advanced highly mobile, multi-band multi-mode communications receiver and transmitter architectures with special emphasis given to techniques, which minimize power dissipation for near optimal performance over a wide range of channels. Survivability in an electronic information warfare environment is a requirement.

5.1.8. Realistic simulation of future battlefield communications with hundreds or thousands of nodes is computationally unwieldy. Modeling and simulation techniques to facilitate these simulations are highly desirable. In particular, modeling of ultra wideband channels, channel parameter estimation, signal design, and coding for multiple access channels with interference are important. Many military communication systems signals have unknown or time-varying characteristics, motivating the need for research in both the theory and modeling of stochastic signals in noise and interference.

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5.2. Information Processing and Fusion and Circuits.

5.2.1. Image Analysis and Processing. Of paramount importance is the understanding of image background, including target-competitive clutter, and of how image background compounds the difficulty of target detection and recognition. Available models for background and clutter are currently inadequate. Objective measures of clutter and modeling paradigms that enable the quantification of image properties are needed for effective comparison of scenes, evaluation of algorithm performance, validation of synthetic imagery, and strategies for data fusion. Research is needed which addresses: (i) modeling of background and clutter, (ii) definition and assessment of clutter metrics, (iii) the manner in which clutter degrades the discrimination processes, and (iv) interaction between image background and targets.

The three dimensional (3-D) to 2-D projection process causes object recognition from images to be an ill-posed problem. The detection, recognition, and identification of an obscured, concealed, or partially occluded object in an image of a scene cluttered with other target-like objects is a difficult and challenging task. The problem may be aided by the knowledge of the context, the nature of the ambient conditions (weather, terrain, clutter environment), and other relevant parameters. Algorithms for detection and classification of targets with small numbers of pixels in images with substantial background clutter, such as in forward-looking infrared (FLIR) images are important. Algorithms to examine images with objects which have motion and can be observed over a number of sequential image frames is appropriate.

Research is needed which addresses: (i) the object recognition issues in general, (ii) how the use of a priori and emerging knowledge and alternative data representations may contribute to the solution of the recognition problem, and (iii) how the performance of the resulting algorithm/system may be evaluated.

The development of algorithms for automatic target recognition (ATR) must address highly variable target signatures in highly variable scenes and a variety of sensor types, both imaging and non-imaging. Simulation is the only economical and practical means for providing large amounts of data for parametric studies upon which the underlying theoretical foundation of ATR depends. There is a need to develop methods and metrics for validating the accuracy of simulated data. Simulation produces images which may be realistic to the eye but contain artifacts that could cause difficulty for algorithms. The methods and metrics must detect and represent these differences. In particular, performance quantification based on synthetically generated data lacks creditability without a "validation data set" within every group of environments. Environments consist of meteorological states, target operational states, and target distortion ranges. Metrics to quantify data states and ranges for synthetic data calibrated using real data are needed to create "validation data sets" to enhance the credibility of test results.

Currently, there are no effective methods for predicting the performance of an Image Analysis and Processing system, given the input signal or parameters of the scene such as time of day or nature of clutter. There is a need to both understand the sensor and to represent the information content in the signal and how it affects the algorithm performance. As part of this effort, it is necessary to develop metrics that predict theoretical performance bounds and estimate how close the actual performance is to the predicted and optimal performance. Methods for characterizing the complexity of data/signals are required so that performance metrics can be used to compare different algorithms across different data sets.
There is a need for development of fast ways to perform such computations, especially for applications which demand closed loop execution, such as missile guidance. If fast implementations of such algorithms require special purpose computing architectures, then such architectures may be considered a component of the research. However, it is preferred that algorithms be developed for architectures that can be upgraded or improved at least every 18 months. The challenge for the future is to implement a modular, cost effective, embedded signal processor that is "incrementally" upgradeable and not anchored to a particular vendor or processing element, and that can be optimally configured for specific applications and algorithms.

There are multiple sources of data being transmitted for many diverse uses, e.g., ATR, mine detection, telemedicine, tele-maintenance, visual display, cueing, etc. The coordination of the source coding compression methodology used and the application requirements are paramount. Compression methodology must be matched to data characteristics and application needs. There is a need to develop compression approaches that fulfill the multiuse requirements.

Model-based target detection, classification, recognition, and identification rely on databases consisting of models of target signatures, clutter signatures, etc. In real-world mobile scenarios, algorithms have to take into account thousands of potential target types, many of which are poorly characterized due to lack of training data, some of which may even be previously unknown. Algorithms also have to deal with continuously changing clutter and/or occlusion characteristics. The databases necessary to support model-based target identification are unlikely to be small enough, or well-characterized enough, to support real-time mobile applications. Some means of constructing and refining models "on the fly" from the input data stream is required. A sound theoretical basis is needed for such "agile" or "adaptive" modeling. For example, just as a conventional nonlinear filter is capable of extracting a low-observable target from the background and recursively refining an estimate of its state thereafter, so the desired "modeling filter" would initiate and recursively refine an estimate of the model of each target type (and perhaps also of clutter/occlusion processes) as they are encountered in a continuously evolving scenario. This research enables more efficient utilization of model databases and dynamic environments for the purpose of multi-source, multi-target, detection, classification, recognition, and identification.

5.2.2. Information and Data Fusion. Multisensor and multidimensional data acquisition systems are becoming increasingly prevalent with sensing platforms remotely distributed on the battlefield. Processes such as target detection, classification, recognition, identification, and tracking often require fusion of information, much of which takes increasingly diverse forms and which is increasingly supplied by remotely distributed sources. To date, approaches to this general fusion problem have been addressed in heuristic, piecemeal, and disjoint fashion. Rigorous and heuristic approaches which have been used in this process include classical or Bayesian statistics, Dempster-Shafer, fuzzy logic, rule-based inference, plausible reasoning, rough set theory, and statistical capacity theory. A variety of information-quality measures are associated with these approaches: likelihood, possibility, belief, entropy, etc. Further progress in data fusion requires that the following four aspects of the fusion problem be addressed in a more systematic, unified, and theoretically sound fashion: (i) data representation, (ii) data encoding and transmission, (iii) pooling of diverse data into a coherent picture, and (iv) measurement of the informativeness of both data and the fusion system. Ideally, a systematic, tractable framework is needed that will allow diverse input data streams to be transformed into a unified information fusion space for processing using more unified and tractable procedures, and which will permit performance to be measured with greater confidence. This framework must be open (i.e., permit growth in an emergent or epistemological process) and should provide systematic, tractable measures of information quality.

First, much information is corrupted by forms of ambiguity more extreme than those addressed by conventional statistical analysis: imprecision, vagueness, indiscernability, partial contingency, etc. Image data, in particular, presents unique difficulties. It is important that information from sources such as images, signals, voice messages, geographical information, natural language text, features and attributes, and rules from knowledge bases be presented/modeled in a unified framework (especially multidimensional data representations that are scalable in spatial and temporal resolution). For heterogeneous image and video data, it is known that scalable data representations offer advantages for fusion processes.

Second, current data fusion systems separate the problem of data transmission (from sensors to fusion processing) from the information needs of the fusion algorithms or human end-users. Since much of this data is accessible only via a communication network, fusion systems require variable amounts of data compression depending on such factors as congestion, mission, target priority, algorithm needs, end-user requirements, etc. (facilitated by a scalable data representation).

Third, mathematical methods for representing and fusing information from multiple sensors are fundamental (especially multidimensional data representations that are scalable in spatial and temporal resolution). Effective means are required to fuse diverse information originating from many sources into a single composite picture. A common example is track-to-track fusion, in which existing and possibly correlated or conflicting estimates/ decisions must be fused into a valid composite picture. Another example is that of fusing the (possibly correlated) decisions and/or estimates provided by a number of experts or fusion sources, each employing different evaluation criteria and using possibly overlapping data sources.

Fourth, a mathematical framework is essential for tractable means of measuring information content in diverse and ambiguous data. Evaluation of fusion system performance requires techniques capable of representing preferences, expert credibilities, weights of criteria importance, and data dependences in qualitative terms that lead to an aggregated choice of alternatives which are preferable or admissible but not necessarily optimal. Such measures should enable prediction of the level of system performance based upon the information content of sources available, knowledge gained from previous experience, tasks to be performed, and constraints in the context of the task to be performed.

Threat assessment is the process of estimating the current threat status of a target. Battle Damage Assessment (BDA) refers to determining the threat status of a target after an attempt has been made to destroy or disable it. Issues which require further research include more systematic approaches to threat assessment and BDA which permit effective post attack evaluation. A common methodology should be developed that would support the optimal determination of current threat state based on reports gathered from multiple information collection resources.

5.2.3. Information and Signal Processing. Information and signal processing research is oriented primarily toward infrared image analysis for target detection, classification, identification, and tracking and sensor fusion. Interest exists in high performance multi-dimensional and concurrent signal processing architectures and novel and hybrid implementations such as fuzzy and neural networks, discrete event dynamical systems, and non-linear systems using electronic, biological, optical, acoustical, electro-optical, or acousto-optical techniques. Important aspects of this research include the development of design methods, architectures, and implementations to minimize power dissipation, to increase processing speed and concurrency, and to increase modularity to aid implementation of incremental upgrades.

5.2.4. Circuits. There is a need for original research on novel circuit designs which utilize new integrated circuit, acoustic wave, and/or photonic technologies to improve operating performance. Improvements are sought in performance parameters such as reduced noise, reduced power dissipation, and increased speed. Extending the bandwidth, time-bandwidth product, and upper frequency limits of circuits is included. Design tools for integrating RF devices and components, such as inductors and optics, on chip are needed to reduce size, weight, power, and cost. Circuits such as mixers, oscillators, amplifiers, phase-locked loops, voltage-controlled oscillators, digital-to-analog and analog- to-digital converters, correlators, and convolvers may benefit from this research. Typical goals may be to develop technology for implementing monolithic transceivers on single integrated circuits and processors capable of multiple gigahertz operation.

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5.3. The Systems and Control Program is concerned with modeling, analysis, and design of complex real-time systems, especially as they relate to Army problems in distributed command, control, communications, and in guidance and control of complex autonomous and semi-autonomous systems. The program invests in fundamental control theory, intelligent systems, sensors and actuators, and design and control of smart structures. Additionally, the program seeks to invest in issues related to new and emerging interdisciplinary areas of control such as control in quantum systems, nanotechnology, and biological systems.

5.3.1. Control Theory. Topics of interest include multivariable control for robust performance in the presence of measurement and model uncertainties including adaptive, nonlinear, optimal, stochastic, and hybrid control. Additional areas of interest relate to new and novel applications of control such as control in quantum systems, nanotechnology, and in biology.

5.3.2. Intelligent Systems. An intelligent system seeks to configure assets to achieve goals or to replan objectives in a fault tolerant fashion, either autonomously or for intelligence augmentation of human-centered systems. Intelligent control is the avenue by which regulatory control systems will be expanded to more general functions of decentralized decision making, goal selection, mode switching, assistance to human operators, scenario identification, and system adaptation. Topics of interest include computational vision, computational geometry, cognitive issues in man-machine systems, hierarchical sensing and control, frameworks for representing and reasoning with uncertainty, soft computing and evolutionary approaches to the design of complex systems, and novel modeling and computational paradigms for large intelligent systems.

5.3.3. Net-Centric, Distributed, Autonomous and Semi-Autonomous Systems. Topics of interest include integrated agent-based decision and control architectures, dynamic resource management, and fault-tolerant operation, especially under bandwidth communication, and computational constraints. One application area that is of particular interest is coordination between and among groups of unmanned aerial and ground vehicles. Another application is the need for ground vehicles that interface with battlefield database information systems to assist a vehicle operator in achieving maximum lethality on the battlefield. Related work includes differential gaming for missile and unmanned ground/aerial vehicle pursuit-evasion.

5.3.4. Control of Hybrid and Embedded Systems. A hybrid controller may be defined as a conventional analog controller that changes states or control modes at discrete times. Design of such systems requires analysis of the effects of random delays and investigations into issues of autonomy, hybrid dynamics, and discrete event and hybrid system supervisory control.

5.3.5. Modeling and Control of Logistic Systems. Robust logistic policies are needed that can withstand intelligent adversarial attack. This area includes a need for rapid-response, reconfigurable supply chain designs with guaranteed stable transition dynamics; analyses of the interaction of command and control networks and materiel distribution systems; closed-loop control of force deployment and battlespace management; and stability and performance analyses of large-scale networked systems under uncertain and incomplete information.

5.3.6. Design and Control of Smart Structures. The Army is interested in developing a capability that includes a combination of mathematical theories of design, control, analysis and visualization that would aid in the search for an optimal or near-optimal design of smart and adaptive structures. Topics of interest include advancing the state of the art in active control of materials and structures via first principles modeling, analysis and computation, enhancing the theoretical foundations of controlled fluid-structure interactions at various length scales, developing the communications and hierarchical control theory needed for controlling very large arrays of sensors and actuators and developing engineering tools for design and fabrication of controllable materials.

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5.4. Software and Knowledge-Based Systems. The program in Software and Knowledge-Based Systems (SKBS) addresses the integration of the theoretical bases for the analysis, design, development, and evolution (sustaining) of advanced information-based systems. The research in this program is focused on research that is deemed critical to enabling technology-development that supports a modern system/software engineering capability. The following topics/sub-topics are of particular interest: concurrent system design (hardware/software), embedded systems, modeling and simulation, machine learning, knowledge/acquisition/ representation/ synthesis, intelligent agents, and knowledgebases/databases. The four major foci of the program are explained below.

5.4.1. Software Prototyping, Development and Evolution. The "Software Prototyping, Development and Evolution" (SPDE) area addresses the scientific/engineering advances needed for the implementation of iterative/adaptive graphically-driven interfaces (for engineering design, etc.); rapid prototyping; software generation; system evolution and software reuse; system/software simulation; distributed software change/evolution; software engineering for domain-specific architectures; tools and toolset integration; software/system documentation (requirements/design); and system validation and verification. Formal models and methods (FMM) are addressed separately because of traditions of research and the importance of FMM to the overall analysis and design concerns. Advances in SPDE technologies are expected to contribute to the development of capabilities for engineering robust, safety-critical, real-time and high assurance systems.

A summary of FMM research interests is provided below. The combination of the SPDE and FMM efforts are synergistic and are expected to facilitate the development of a modern basis for a principled "end-to-end" system/software technology-supported engineering capability.

5.4.2. Formal Models and Methods for Software Engineering. The scope of this foci (FMM) includes the concern for network-centric/distributed information-systems and the global dependencies intrinsic to many of these modern systems. However, many aspects of these type of systems can be treated as parameters of a general, overall, design-space. The resolution of issues related to these concern/design-parameters is expected to be addressed via the emerging capabilities contained in the SPDE and FMM techniques. Included in the scope of the FMM foci is interest in research on real-time software issues and the investigation of formal frameworks, deductive methods, and tools for the implementation of provably correct (reactive, real-time and hybrid) systems. As part of a near-term strategy, to demonstrate the "value-added" of the nascent technologies being developed in the FMM element of the SKBS program, there is a strong emphasis on the application-domain of embedded systems. In a broad sense the critical-technology-needs issues, that in part define a critical-research path, include the recognition of the need for coupled technologies enabling the rapid capture/validation of requirements, the semi-automated translation of languages (from development languages to analysis/design languages), scaleable formalisms for analysis/design, code generation, content-based retrieval of archived information, engineering level interfaces, and requirements/design documentation.

5.4.3. Knowledgebase/Database Science. Complex reasoning in a real-world environment requires the ability to integrate data from multiple databases (relational databases, object-oriented databases, geographical information systems, etc.) and data structures as well as to adopt and integrate multiple modes of reasoning such as inconsistency, time, planning, scheduling, reasoning under uncertainty, reasoning under incompleteness and reasoning about pictures, images, and sound. Much of the data/information in the world does not (and will not) reside in any conventional database but rather resides in data exchange (DX) formatted files. Only a few DX formats and their application programming interfaces (API) have database management features. This fact along with other characteristics of DX files leads to a number of research issues such as concurrency control, support of behavioral components and query languages. There is interest in these several areas as well as in content-based retrieval, complex reasoning and machine learning. Agent technologies and the enablement of the many decision-support application needs (facilitated by information fusion) are also of interest to the SKBS program.

5.4.4. Virtual Parts Engineering Initiative. This is a critical application of the generalized SKBS program technology-enablement objectives. At present there are numerous CAD tools; however, they generally cannot be used together. As importantly, while we have enabled CAD we have not facilitated CAD/CAM. It is the objective of this thrust to not only contribute to solving the interoperability problem, but to facilitate the coupling of CAD and CAM. Part of this effort is attempting to build on the emerging international data standard for physical-systems (STEP). At present STEP has some significant features and utility; however, the emphasis in this initiative is to enhance STEP thru research that addresses the many non-physical dimension concerns of designers. Of particular interest are the issues of reverse-engineering, reengineering, and redesign capabilities. The "Legacy System/ System-Part" engineering and procurement concerns/costs give this area a particularly high potential return on investment.

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5.5. Information Assurance. From the Army perspective, Information Assurance must address the delivery of authentic, accurate, secure, reliable, timely information, regardless of threat conditions, over the distributed and heterogeneous computing and communication system. The computing system may range from a hand held mobile unit to a centralized high performance information processing system. Heterogeneous communication systems consist of both tactical (mobile, wireless) and fixed (wired) communications infrastructures.

5.5.1. Supporting Army Mission Characteristics. The objective of this research is to enable dynamic management of communities of interest (COI) by the battlefield commander. The commander needs the ability to alert the membership in a specific COI based on issues ranging from classification of the data to specifics of the battlefield situation. If, for example, the information device of an individual war fighter is captured by the adversary, the commander must recognize that change in status and deactivate that node to protect subsequent transmissions. Individual war fighters may simultaneously be members of multiple COI's depending upon battlespace specifics. Research is needed in the areas of protocols and techniques which support reconfigurable, survivable and self-healing, efficient, and mobile computing and communication environments that would allow for the dynamic creation of Communities of Interest as well as to assure delivery of trustworthy data within reconfigurable, mobile network environments. Reconfigurable, survivable and self-healing systems allow a combat unit to dynamically establish and maintain its command and communication capability under diversified and extreme battlefield situations. Efficient computing and communication is another important aspect of information assurance that needs to be addressed. Most likely, the battleground system (both attended and unattended) relies heavily on limited energy resources to perform its functions. New computing and communication protocols and techniques need to be developed so that critical information delivery and critical infrastructure functions can be assured, while maximizing the longevity of such systems under the resource constraints.

5.5.2 Supporting Battlefield Technology: Information Protection for Wireless Networks. The Army requires a fully mobile, fully-communicating, agile, and situation-aware force that operates in a highly dynamic, wireless, mobile networking environment. This force consists of a heterogeneous mixture of individual soldiers, ground vehicles, airborne platforms, unmanned aerial vehicles, robotics, and unattended sensor networks that operate in a complex wireless environment. The objectives of this initiative are to 1) develop techniques and a quantitative basis for intrusion or anomaly detection and vulnerability assessment of mobile wireless networks that is automated, efficient, scalable, adaptive, and secure; 2) develop security services and wireless security infrastructures for highly mobile tactical and unattended sensor networks that are distributed, scalable, and extremely resource efficient, and, 3) develop a fundamental understanding of the trade-offs and limitations on detection performance, coverage frequency, adaptation rate, wireless capacity, security, complexity, and parameter sensitivity under bandwidth, energy, processing capability, bit-error-rate, and mobility constraints. Research areas include tools and techniques for automated wireless intrusion and anomaly detection, automated wireless vulnerability assessment, mobile wireless security infrastructures and sensor network security infrastructures, as well as secure and trustworthy mobile code in tactical operations.

5.5.3. Evaluation Metrics and Risk Mitigation Methods. Information Assurance metrics are scarce and qualitative. Given the need to determine the information assurance posture for a given organization under given conditions, commanders in the field require a means to determine the relative degree of assurance associated with the information assets under their control. Likewise, developers of Army systems require metrics to measure the degree to which they are employing security engineering practices during the system development process. The use of IA metrics would permit establishing trust in a system built from untrusted components, determining sufficient levels of security for the specific tactical situation and condition, and assessing system vulnerabilities.

5.5.3.1. *Information Assurance Metrics in the Tactical Environment.* IA metrics development should focus on measures of assurance for specific in-place systems and for systems development activity. These metrics are intended to be used to guide commanders in understanding the security posture of the systems they depend on in information operations and to guide Army developers in determining the degree to which they are adhering to good security engineering practices. These metrics are particularly important when systems are formed from other systems or many COTS products are tied together. A goal is to discover a means of providing sufficient security to meet present threat and provide operational flexibility to the commander in the field. Finally, solutions are sought to the human factors problem associated with security of Army systems (e.g., unintentional compromise, security relevant error, intentional insider attack). Research is encouraged in the area of measures and metrics associated with assurance determination of existing systems (particularly when the existing security perimeter has been modified operationally) and for the security engineering process associated with new development (which includes new code and COTS composition). Means of matching the security protection mechanisms to the existing threat and modifying this set of factors as the threat changes are sought. Research into processes and procedures that minimize human error and vulnerability introduction is encouraged.

5.5.3.2. *Testing, Assessing, and Mitigating System Vulnerabilities.* The objective of this research strategy is to develop the technology necessary to test, assess, and minimize system vulnerabilities, particularly in the Objective Force environment. This environment will consist of technologies not yet established, such as dynamic, wireless networks. Nevertheless, it is essential that testing, assessment, and risk mitigating technologies be researched *a-priori* so that as these new technologies emerge, the capability will exist to test and assess the security of these systems. This will certainly include finding new vulnerabilities of existing technologies, developing new security attacks and attack countermeasures, and adaptive risk mitigating technologies. These testing, assessment, and risk mitigating techniques must be adaptable to the new technologies as they emerge. Research concentration areas include: (1) System security and vulnerability assessment framework and methodology, (2) Novel security and vulnerability assessment methods, (3) Adaptive countermeasures to attacks and to system vulnerability exploitation, and (4) Framework and methodology for building secure, intrusion immune host and network systems.

5.5.3.3. *Correlation, Fusion, Analysis, and Visualization of Systems Security Information.* The objectives are to (1) develop techniques and a quantitative basis for the correlation, fusion, and analysis of multi-source infrastructure protection data to reliably and adaptively provide attack indications and warning, and (2) develop a scalable, modular, and open visualization and analysis environment that correlates, aggregates, prioritizes, and displays situation awareness data from multiple sources in a way that significantly increases the ability of an analyst to recognize and react to incidents. Research concentration areas include: (1) Multi-Sensor, Multi-Site Event Correlation, Analysis, and Fusion, (2) Methodology and techniques to improve the quality of attack indications or warnings, and (3) Visualization and Presentation.

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RESEARCH AREA 6
PHYSICS

6.0. The objective of the Physics Program of the Army Research Office is to develop and exploit the physics knowledge base for new Army needs and capabilities. The future promises dramatic changes in military capability as a result of physics research. In support of this goal, the interests of the Physics Division are primarily in the following areas: Condensed Matter Physics; Theoretical Physics and Nonlinear Dynamics; Quantum Information Science; Atomic and Molecular Physics; and Optics, Photonics, and Image Science. Physics disciplines which impact these areas include: (i) Condensed Matter Physics, (ii) Interface/Surface Physics, (iii) Atomic, Molecular, and Optical Physics, (iv) Materials Physics, (v) Cross-Disciplinary topics, and (vi) Classical Phenomenology. There is little direct interest in Relativity and Gravity Physics, Elementary Particles and Fields Physics, Nuclear Physics, Astronomy, and Astrophysics since they generally have no impact on the research areas of Army needs. Nevertheless, the possible relevance of topics within these other physics disciplines is not absolutely discounted and discussions of potential exceptions are welcome.

The disciplinary boundaries of the ARO are not sharply drawn as shown by the joint support of a number of efforts by the Physics Division and other ARO Divisions. In addition, it is not necessary that a potential chief investigator be associated with a Physics Department to receive support from the Physics Division.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a preproposal.